September 30, 2011

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VIA ELECTRONIC FILING

Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

Re: GN Docket No. 11-117

Dear Ms. Dortch,

The filing presented in the subsequent pages discusses a mechanism by which position determination accuracy for indoor subscribers making E911 calls can be substantially enhanced. This is accomplished through the introduction of electronically manufactured reference signals that are automatically processed by the CDMA positioning system. These techniques have been deployed within the confines of an airport terminal and across a college campus with significant success in both environments. Two locations begin to provide anecdotal evidence of efficacy but for statistical significance many more venues would need deployment studies to be performed.

The discussion that follows provides a summary of the problem and solution, an introduction about the author, and a detailed discussion regarding the causes and solutions to the indoor location challenge broken down into four common scenarios.

If as a result of this submission, members of the FCC community wish to engage in additional dialog, please feel free to contact me at your convenience.

Kind Regards,

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Attachment Follows:

Re: Response to July 12, 2011 FCC request for comments on Improved 911 Availability and E911 Location Determination for VoIP

Summary Statement:

Subscribers of CDMA service providers use mobile phone measurements of GPS and cell site downlink energy arrival times to feed a Position Determining Entity (PDE) server with the raw data from which locations are determined. When these subscribers move indoors geo-location accuracy degrades due to a lack of sufficient reference signals to measure. Repeaters or distributed antenna systems (DAS) deployed to enhance voice and data coverage and capacity add distortions to the indoor measurement signals, which often generate severe errors of many hundreds of meters for more than half the subscribers. These errors can be mitigated cost effectively, without any changes to phone or PDE hardware or software, through the addition of Co-Pilot Beacons (CPB). CPBs can be injected into the DAS or repeater such that the indoor environment becomes dense with position reference signals. When the RF environment is enhanced with CPB position reference signals, studies and initial deployments offer substantial anecdotal evidence that location accuracy on the order of 100m is possible a significant majority of the time. Estimated cost increase for the DAS to enhance rather than degrade the positioning system for indoor subscribers is less than 10% (25% for standalone repeater enhancements).

Comment Motivations:

"The Commission today also required all wireless carriers to test their E911 location accuracy results periodically and to share the results with PSAPs, state 911 offices, and the Commission, subject to confidentiality safeguards. The Commission referred to the Communications Security, Reliability, and Interoperability Council (CSRIC) the task of making recommendations to the Commission in six months on specific, cost effective testing requirements and methodologies"……

"The Commission is also seeking input on ways that location technologies that are already being developed for commercial broadband applications might be leveraged to support 911 location determination. Finally, the Commission is soliciting comment on how to improve location accuracy for 911 calls made from indoors, including large office buildings where it may be difficult to locate an individual in trouble based only on a street address, and directed the CSRIC to develop recommendations for cost effective indoor location accuracy testing."

About Phil Ziegler:

Phil Ziegler is recent founder of Phil Ziegler Consulting, LLC and a member of the Evolutionary Communications Consultants (EC^2), LLC team providing support to organizations deploying wireless in building network solutions. Prior to launching his consulting career, Phil served the Verizon Wireless (VzW) HQ organization as an in building technology subject matter expert. In this capacity he created the VzW standards for deploying in building solutions. Prior to his tenure with VzW, Phil served in a consulting capacity to ITT ACD during their development of the Navigation Payload for the GPS Block 2R constellation and developed positioning algorithms for the JTIDS and ICNIA military C3I systems. Phil has also worked at Lucent Technologies in their Wireless Design Center and Systems Engineering Groups, as well as Telcordia's Engineering Services and Tools Development organizations.

General Overview:

Several studies conducted by industry and universities indicate that in building position determination is challenging under a variety of circumstances. GPS signal levels are often inadequate to penetrate throughout buildings with significant external structure. This fact is compounded in urban areas where obstructions block and reflections distort contributions from satellites in the GPS (or other) constellations. Terrestrial positioning systems based upon Wireless Service Providers' cell towers and base stations using either forward or reverse link time difference of arrival measurements are similarly effected by reduced signal levels, obstructions and indirect radio link pathways. Perhaps less obvious are the adverse effects voice and data indoor enhancement techniques have on positioning.

Repeaters add delay to signals captured by their donor antenna. These introduce errors into the apparent path length between the subscriber and the reference point. However, not all measured signals are necessarily repeated. Due to the fact that signal levels necessary for position determination can be substantially lower than those needed for acceptable voice and data communication, it is likely that some measurement energy between base stations and subscribers (or subscribers and base stations) will travel through a non-repromulgated path. Therefore standard position determination system features that compensate for clock bias or drift are unable to find a single applicable offset that improves solution convergence.

Distributed antenna systems (DAS) of both the outdoor and indoor variety also adversely affect the indoor subscribers ability to determine position. Characterized by simulcasting, slow propagation through fiber and an indirect path between the RF source and the transmitting antenna, DAS deployments create location solutions with high degrees of uncertainty. RF sources that are coupled to fiber DAS environments are often disqualified from being used in position determination solution creation. Further complicating matters is the fact that when a DAS is deployed, it is desirable to have a low noise floor in the building being covered. Cells surrounding the DAS coverage objective affect the noise floor and since the energy from those cells are deemed interference are often either reduced or directed away from the DAS coverage objective building. However, signals that are interferers with voice and data communication may be valuable contributors to the array of vectors that determine position. Therefore by reducing their energy position determination accuracy is further degraded.

There are many dimensions to the problem of indoor position determination; however creating a local reliable reference signal or compensating for the distortions in the measurements being collected may easily mitigate many of these problems. The focus of this submission will be to describe how a co-pilot beacon (CPB) signal can be added to the CDMA 2000 waveform so as to improve indoor position determination in solutions using GPS, Hybrid (GPS and terrestrial reference points), Advanced Forward Link Trilateration (AFLT, where the solution is based exclusively on terrestrial measurements), Mixed Mode solutions (those that combine terrestrial measurements and sector geometries) as well as techniques that are exclusively geometrically based.

Detailed Comments

The information provided below applies to CDMA based E911 systems that are facilitated by the Qualcomm/Snaptrack system, whereby measurements made by the cell phone of CDMA reference signals are provided to a network server known as the Position Determining Entity (PDE). The PDE uses almanacs to obtain point of origin information regarding the reference signals. These almanacs are of two types, one for the members of the GPS or other satellite constellations and the other for the fixed network elements associated with the terrestrial reference points. These reference points are typically considered base station sectors, which can be uniquely identified by a code know as a PN. All reference transmitters, either space borne or terrestrial, require almanac entries. The almanacs provide data to the PDE, defining the points of origin for the reference signals. This enables time difference of arrival measurements to be applied to distance determining equations, which in turn create distance scalars to each reference point.

There are fundamental assumptions that the RF energy used in the measurements has traveled at the speed of light and along a straight-line path between the source and the measurement device. If the measurement energy is delayed or does not travel in a straight line, the apparent distance to the reference point contains significant distortions. However, when a sufficient number of distances can be "accurately" determined, the algebraic solutions converge with confidence and a subscriber's position can be derived. When insufficient reference points are available the system does its best to create solutions based upon geometric algorithms that identify locations with less precision and confidence. Simply stated: The more references that the subscriber's phone can see/hear the better the solution.

Finding a "sufficient" number of "acceptably accurate" distances to reference points such that position determination equations converge on a location solution characterized by both confidence and precision (on the order of 100 meters or ~3 arc seconds) is made difficult indoors by the factors described in the previous section. The questions are therefore proposed as to how indoor reference points can be deployed and how will location solutions be improved by the addition of such reference points, when they are deployed in or near buildings whose structures preclude access to existing base station and satellite references.

CDMA base stations are complicated transceiver devices creating at least four and as many as 20 transmitted sub-channels of CDMA energy in each 1.25 MHz of downlink carrier bandwidth. However, only the Pilot sub-channel is used to determine the range to the transmitter. The Pilot sub-channel typically uses 15% of the total power of the channel, but no information is added to the basic digital signal characterized only by its PN and Walsh code 0. It is a digital whistle requiring relatively little sophistication to manufacture. When the time of arrival of the Pilot is measured, it is done so with an accuracy of 50ns, which is approximately 15 meters. For good voice communication, measured in bit or frame error rates, it is necessary that the pilot sub-channel be heard such that its signal to noise ratio Ec/Io is no worse than ~-14dB. However, when used as a ranging beacon, signals down to an Ec/Io -30dB are still identifiable. That is, one can use the Pilot sub-channel for ranging long after it has decayed beyond the useful threshold for the other sub-channels to be demodulated accurately. This 16 dB of difference in power translates to a 5 fold increase in distance it can travel through free space or several interior building walls, and still be usable. Therefore, when trying to determine position from terrestrial reference points, the set of references that can be used is a significant super set of the sources that can be used for communication of information.

Pilot beacons have traditionally been used outdoors by CDMA Wireless Service Providers (WSPs) for facilitating hard hand downs between areas of greater and lesser carrier density. A Co-Pilot Beacon (CPB) is defined to be a pilot signal generator that produces a pilot like signal inserted into the carrier as a supplement to the overhead set of sub channels. It is characterized by a PN different from that of the traffic channel making it uniquely and locally identifiable. The CPB has adjustments that can alter its power output and its time base. The amount of energy or timing advance necessary is dependent upon where and how the CPB is coupled into the in building augmentation solution. The CPB needs a timing reference, which can be either pilot and sync overhead sub-channels from a base station or an external GPS source. The ability to adjust the PN, advance or retard timing to compensate for delays introduced by the in building coverage enhancement system and throttle the power, allows the CPB to couple into the environment at the most convenient location and still provide the reference needed by the in building subscriber.

By tactically locating CPBs, providing them with almanac entries, and placing them on the neighbor lists of traffic sectors, mobile devices quickly and reliably receive fixed location references that allow the network to determine a handset or mobile device's specific location. The position information can then be used to aid the GPS receiver in acquiring signals, if they are present, or it can be used directly as a terrestrial reference that is local and precise. This facilitates substantially more accurate position determination for both E-911 and commercial applications, without any changes to the existing location server, mobile device or base station hardware. Once the CPB transmitter is activated and coupled into the DAS or Repeater all that is necessary are additional entries into the databases already in place.

There are four deployment scenarios that shall be considered. They are:

1. An outdoor DAS such as might be deployed on a University Campus
2. An indoor DAS such as might be deployed in a Multi-Terminal Airport
3. A building where coverage and capacity is augmented by a Repeater or stationary signal booster.
4. An underground train tunnel that could be several miles long where emergency access points for first responders are thousands of yards apart.

In each of these circumstances the addition of reference points will require detailed engineering design efforts, however those details will not be discussed herein as they would be a function of the particular DAS or Repeater equipment in use in the venue, and there are just too many options to be analyzed. Rather, a discussion of the generic circumstances that cause location determination problems in each scenario, the relative amounts of energy needed, the nature of that energy, and post deployment accuracy improvements will be provided.

CASE 1: The University Campus

Situation: Several hundred buildings are distributed over a 500-acre campus area. The macro network provides coverage to 75% of the campus property and 50% of the indoor area but not all students can use their cell phones in the dormitories and there is no service is many classroom buildings and dining halls. The University trustees believe that the campus will be safer were coverage to be more ubiquitous and put out an RFP for a campus wide outdoor DAS. Similar situations to this scenario either have occurred or are occurring in several dozen campuses nationwide.

Coverage Solution: Wireless Service Providers agree to participate on the DAS and raise the coverage levels to 97% outdoors and 85% indoors. To achieve this objective, engineers determine that 24 DAS nodes are required. That is to say there will be 24 locations distributed over the 500 acres radiating sufficient RF power to cover the campus ubiquitously and blast into the buildings. Based upon the needs of the campus population and available budget, a Wireless Service Provider is prepared to deploy two CDMA base stations delivering six sectors of capacity to the campus. Each base station sector is an RF source with a unique "signature" and simulcast to 4 locations. Simulcasting refers to the concept that identical signals from the same RF source will similarly radiate from multiple nodes or locations.

Further, CDMA communication system efficiency is adversely affected by the background noise that needs to be overcome. To maximize the capacity of the on campus sectors, energy from the surrounding macro network is attenuated or redirected away from the campus, which lowers the noise floor. After the deployment, the coverage objectives are met and the trustees have the near ubiquitous coverage desired.

Impact on E-911 System: GPS signals do not penetrate the buildings very well due to shadowing among the buildings themselves and significant energy losses through the exterior walls. Even where there may be adequate penetration to ultimately gain a GPS location, the losses and resulting low signal level may result in acquisition times so long that the GPS information is not available when needed. Therefore, position solutions need to be based on the higher energy terrestrial reference points. However, the nature of the DAS is such that energy from the RF sources (base station sectors) is distributed through the university's fiber plant. Fiber optic connections to DAS nodes create four problems for the positioning system.

1. Connections between RF sources and the DAS nodes do not take a direct i.e. straight line path.
2. The speed of light through fiber is only 2/3 as fast as the speed of light through the atmosphere.
3. The fiber path and therefore length to each simulcast node is different, therefore rather than a consistent error, each node carries with it a unique error that cannot be tuned out.
4. The almanac records are created based upon the geometric assumption that the reference signals originate from a single radiating antenna. When multiple nodes radiate the same reference signals there is no mechanism in the almanac to identify the origin of those signals.

As a result of these factors, the distances calculated to the reference points are prone to large errors, which corrupt the solution. The result is that indoor position determination solutions become pathologically distorted. If the measurements are used, then the solution will converge to points very far away from the subscribers location; if the measurements are disqualified then there are an insufficient number of reference points for algebraic solutions. Both pathologies often create position determination errors of more than a kilometer. At the 2011 DAS Congress held on May 23-25 in Las Vegas, Steve Ambrose, DAS Deployment Manager, Texas Christian University stated that the on campus PSAP knows that the locations of callers making E-911 calls contain errors and uncertainties so gross as to be unusable by first responders. Efforts during 2010 at Texas A&M to evaluate E-911 position system efficacy from calls made in dormitories after a DAS was deployed, indicated that position errors reported to the PSAP often exceeded a kilometer from the callers actual location.

Mitigation: The almanac records of the primary base station sectors have disqualification flags set to true. Supplemental pilot signal generators (Co-Pilot Beacons or CPBs) are then deployed in the outdoor DAS environment such that several of the DAS nodes have a fourth overhead channel injected into the CDMA 2000 downlink carrier. The deployment can be implemented by coupling the CPBs into the DAS either where the serving sectors' RF energy is split into individual fiber paths or at the outdoor nodes themselves. The CPB channel is broadcast at 8 dB less power than that of the carrier's primary Pilot channel. (Therefore in band power increase is only 2% to 4%.) These relatively low power signals travel further in free space and are useable indoors at much lower energy levels. Since the DAS simulcasts the primary communications channels, multiple CPB instances are necessary to support each sector, however a one to one overlay at each DAS node might not be required. RF engineering analysis and signal level measurements indoors provide an indication of what subset of DAS nodes would need to be enhanced by CPBs. Therefore, most users have the ability to make measurements from a sufficient set of reference points such that position determination accuracy to within 100 meters is the norm rather than the exception. This was proven to be the case in the vicinity of the five DAS nodes augmented by CPBs at Texas A&M in the fall of 2010.

CASE 2: An Airport or Mall

Situation: Concourses connect several buildings to create a single large structure. Significant open areas (parking lots or runways) surround this large structure and provide a buffer zone to the general community in which cell towers and base stations are deployed. During times when indoor subscriber density is high there is insufficient energy from the surrounding macro sites penetrating through the building to provide service to all those subscribers wanting to use their cell phones. The managers of the facility decide to deploy an indoor DAS to assure that there is sufficient RF energy to meet the needs of the patrons. Public safety considerations make identifying the building from which an E-911 call is placed highly desirable.

Coverage Solution: The DAS is characterized by an array of low power (compared to the previous example) indoor nodes. Whereby outdoor DAS nodes are responsible for covering dozens of acres, indoor nodes are generally responsible for covering less than three thousand square meters or so. (1 acre ~= 40,000 square meters). Three sectors of service provider capacity are responsible for covering more than three buildings that make up the aforementioned structure. So there will exist at least one sector whose coverage footprint extends to multiple buildings.

Impact on E-911 System: Since each dedicated in building sector is simulcast, and RF energy from outdoor reference sources is not plentiful inside, it is very unlikely that algebraic ranging based solutions from either the GPS constellation or the macro network will be possible. However, compared to the footprints of either a macro network sector or even an outdoor DAS node, the footprint of the individual sectors are relatively small. Sometimes in such scenarios capacity and budgetary dictates of the deployment require that the energy from a single sector be deployed into buildings at opposite ends of a concourse. Several hundred meters may separate this pair of buildings. The geometric solutions for location also need information stored in the Almanac's data base record, which were not architected to define discontinuous geometries. Therefore, the geometric footprint of the sector, that serves the two buildings at the opposite ends of the concourse, is defined as the entire structure with a center located in the concourse area rather than in either of the buildings. When the system tries to determine the position of a subscriber in either of the buildings and only a single signal is available, then the subscriber will be located at the center of the coverage footprint of the serving sector, or in the concourse halfway between the two buildings.

At McCarran Airport in Las Vegas Nevada, when the DAS was turned on thousands of position fixes were made in 10 locations across two adjacent buildings. Less than 50% of the points were within 150 meters of their true location and the estimated radius within which 95% of the fixes would be contained was nearly ¾ of a mile away from the true location.

Mitigation: CPBs can be deployed and coupled into the DAS such that in each building a subscriber hears the serving sector's PN and a second PN unique to the building with a coverage footprint defined to not exceed the boundary of the single building. The ratio of serving sector energy to CPB energy is similar to the previous case. The serving sector is simulcast throughout both buildings and the CPBs can be configured to support either algebraic or geometric solutions depending upon the conditions in their individual building. If the CPB radiates from a single point in the building and can be heard throughout, ranging is possible which can improve the yield (higher quality solutions as a result of more accurate measurements being available) of the solution. If there are no other sources available for ranging then the CPB can be simulcast throughout its designated building and contribute to the geometric solution.

In one building the subscriber hears and reports that energy has arrived from the serving sector and the CPB dedicated to the first building, in the other building the subscriber hears the serving sector and the CPB dedicated to the second building. The difference between the combinations of PN signals heard in the two different buildings allows the positioning system to isolate a subscriber to the building of call origin. Were additional signals from the macro network to leak into one building or the other, the combination of PN's heard with small footprints and measurements from macro site sector leakage into the building, will still force the determined position into the footprint of the CPB. The deployment of 4 CPBs in two buildings at the McCarran Airport facility reduced the size of the uncertainty ellipse from nearly a kilometer to just 100 meters in several places.

CASE 3: A Stand Alone Building

Situation: A single building in an office park has tenants that demand the ability to use their cell phones indoors, however there is insufficient RF energy from the macro network to do so. Some nominal levels of energy leak into the building from several macro sectors, which can be used in position determination calculations.

Coverage Solution: To address the needs of the tenants the landlord installs a repeater. The donor antenna is pointed at a nearby cell site and cables are used to penetrate the building shell, which carry the RF energy to the bidirectional amplifier. The amplifier increases the signal levels and rebroadcasts the energy into the building through the coverage antenna. Even though the signals passing through the repeater are delayed between 3 and 5 microseconds, the subscribers in the building are able to make voice and data calls.

Impact on E-911 System: Typically the amount of GPS energy that enters the building is either too weak or comes from too few satellites for the positioning system to use. In suburban communities it is often the case that many signals from the macro network are detectable. Signals from the macro network that provide coverage to the community at large and radiate directly into the ether should not be disqualified. Even though there are repeaters deployed that distort the in-building measurements, most subscribers within the coverage footprint of the macro network sector use these signals to generate distances to the reference locations. The signals entering the building can be classified into two groups, those that go through the repeater and are delayed, and those that do not go through the repeater and are therefore not delayed. Among the signals that are delayed include the primary donor site and any energy from radiating sectors within the donor antenna's beam width. As a result of the distortions introduced into the distance calculations of the repeated signals, pathologic conditions are sometimes created where by the algebraic equations, based upon the two groups of measurements, do not converge. When this occurs geometric solutions are invoked compromising location accuracy and confidence. A second order effect compromises the geometric solutions even further, as the repeater captures signals from sectors further away than should be used in the geometric solution.

In 2010 a study was performed at the University of Colorado's Coors Event Center basketball arena. When hundreds of position fixes were generated during repeater operation, about half of the solutions were outside the building and a significant percentage of those located the caller many hundreds of meters away from the venue.

Mitigation: In the previous two scenarios the base station sectors providing coverage through the outdoor and indoor DAS deployments were disqualified from being used as distance ranging references due to the a priori knowledge that the measurements would be severely distorted. In this scenario, the coverage provided by the serving sector is principally dedicated to subscribers unaffected by the repeater's distortion and as such cannot be disqualified from being a distance determining reference point. A low power CPB is coupled into the coverage antenna and its energy is radiated along with the repromulgated energy from the macro network. Used as both a range reference and a geometric limitation, when turned on the CPB drove over 95% of the hundreds of test fixes into the arena proper with almost no fixes being more than 25 meters away from the building perimeter. (Rameshkrishnaa, G.. Position Determination in CDMA Networks using Pilot Beacons. M.S. dissertation, University of Colorado at Boulder, United States -- Colorado. Retrieved September 6, 2011, from Dissertations & Theses @ University of Colorado System.(Publication No. AAT 1487905).)

CASE 4: A Tunnel More than a Mile Long.

Situation: An underground tunnel running North/South several miles long provides access to a train terminal in an urban area. To facilitate the coverage and capacity needs of the commuters the transit authority decides to deploy a DAS into the terminal and adjacent tunnel system. The tunnel environment does not lend itself to traditional deployment techniques that make use of omni or directional antennas to provide service to the folks in the trains. The tunnel is completely isolated from the macro network except at its mouth, several miles away from the terminal end point. First responders have three emergency egress points from the streets above. Were a catastrophe to occur in the tunnel, incident commanders need to know where to set up the command post and triage areas. Their request is that E-911 callers be located with sufficient accuracy so as to determine where best to set up that command post.

Coverage Solution: The harsh environment requires that strands of leaky coax be used as the antenna system. Again it is assumed that capacity and budgetary requirements allow only a single sector to provide coverage along the entire length of the tunnel. The base stations and therefore serving sectors are located in a head end room in the terminal basement. Energy from the serving sector is sent down the tunnel through fiber to four amplifier locations. There are single amplifiers near either end of the tunnel which are connected to the out board end of the leaky coax strand. Approximately 1/3 and 2/3 the way down the tunnel are the other two amplifier locations. At each location there are a pair of amplifiers. One amplifier sends and receives south bound energy while the other amplifier sends and receives north bound energy. So there are three strands of leaky coax that connect the four amplifier locations. Each strand of leaky coax has an amplifier on each end sending and receiving signals along its course. Therefore six amplifiers are used to provide coverage along the length of the tunnel.

Impact on E-911 System: The three strands of leaky coax all carry the same signal from the serving sector. GPS and AFLT solutions are impossible due to the isolation from the outside world. Therefore all solutions generated without CPB augmentation would simply locate a caller in the middle of the tunnel regardless of where in the tunnel the call originated.

Mitigation: CPBs can be added to the signals radiating from each amplifier. Were six CPBs to be deployed then incident location can be resolved to 1/12 the length of the tunnel. That is, two CPB's located at either end of a leaky coax strand can divide the strand into three geometric areas. All subscribers hear the traffic sector's pilot, which is of little use as it should be disqualified from being measured and covers an area much greater than is required for incident isolation. However, along any of the three strands there is a pair of CPBs that could potentially be heard. The center of the strand is the equal power point of energy from each beacon, therefore when both beacons are heard the geometric overlap of the two CPB footprints will locate the caller to the middle of the strand. As the subscriber gets closer to an end of the strand, the signals from the near end dominate and the signals from the far end fade away into the noise floor. This has no affect on the ability to make or receive a call as both amplifiers carry the traffic. So the only signal fading into the noise floor at either end of the strand is the signal from the far amplifiers' CPB. Therefore, when only one CPB is heard the caller is geometrically located near either end of the strand where that single heard CPB is located, and when both are heard the caller is geometrically located in the middle of the strand. It is theorized and has been experimentally verified that after appropriate compensation for the fiber delay, measurements from pairs of CPBs can add a ranging component to the geometric solution. The linear geometry of the tunnel precludes trilateration solutions, but the measured CPB signals can more precisely locate a caller along the strand, than could be achieved using exclusively geometric means.

The 2010 study conducted at UC Boulder cited earlier included a tunnel deployment scenario that verify and validate the information described above.

Closing Remarks

Indoor subscribers need additional positioning reference points to mitigate their many and varied circumstances. CPBs can be deployed efficiently and cost effectively in many circumstances, regardless of the DAS equipment manufacturer or the nature of the venue. The elegance of this approach is:

1. The CPB hardware is readily available as such devices have been used for other purposes in CDMA networks since their inception for handoff between areas of greater and lesser carrier concentrations.
2. No changes to cell phone, base station, or positioning system hardware or software is necessary.
3. There are already tools in place that can be used to facilitate "tuning" the devices.

The simplicity of the waveform required makes the device inexpensive to produce and deploy. Adding CPBs to DAS based deployments will likely add less than 5% to either power or financial budgets, however the improvements in accuracy are often close to an order of magnitude. In circumstances where a repeater would be used as an RF source, the percentages are likely to be higher.

It is generally advisable to add the CPB to an existing RF source that is already carrying traffic. This assures that the CPB will add negligible energy to the downlink noise floor and is likely to have no effect on network Key Performance Indicators. However, were the CPB to be deployed as a stand-alone unit without the other overhead and traffic sub-channels associated with a CDMA carrier, then it could create a local coverage hole in the immediate vicinity of its emitter.

It is conceivable that different combinations of CPB PN's could be used to distinguish users on different floors in high-rise buildings. Fundamental CPB operation facilitates location accuracy to the building of interest. Then by vertically stacking a group of CPBs the tunnel scenario can be extended into the vertical dimension. The mapping of those combinations in such a way that vertical location is communicated to system operators has not been investigated.

There are challenges to aggressively using CPBs to facilitate indoor location accuracy improvements network wide. Neighbor list planning, PN planning and almanac record creation will eventually need to be enhanced with additional levels of automation to facilitate large scale deployment initiatives. However, the basic technology has been demonstrated and deployed in a live CDMA network, multiple manufacturers of the equipment are in place, and the incremental cost to implement a CPB solution is very small when compared to the cost of in-building solutions that provide basic voice and data service.